Seed Processing

Small Seed Harvesting and Processing Section
Agricultural Engineering Research Division
U.S. Agricultural Research Service
United States Department of Agriculture

Oregon State College
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INTRODUCTION
by
Jesse E. Harmond*

Research dealing with the harvesting and cleaning of small seed is being conducted jointly by the Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, Agricultural Research Service, U.S.D.A., and the Oregon Agricultural Experiment Station at Oregon State College. The activities are varied and include surveys, basic studies, and machinery development--all aimed at improving efficiencies of harvesting and processing operations in the seed industry.

Effective seed cleaning requires a good knowledge of separation principles and machinery operation. This circular was prepared in the attempt to provide some of this knowledge.

Seed cleaning is generally considered to mean the removal of inert matter, weed seed, and other crop seed from the main seed crop. This is accomplished by the use of special equipment which takes advantage of differences in physical characteristics of various components in a seed mixture. Some of the seed characteristics which make separations possible are size, shape, density, surface texture, color, resiliency, and electrical properties.

Manufacturers of seed machinery have done an outstanding job of developing equipment that makes separations which appear almost impossible in view of the minute size of some seeds. Velvet bentgrass, for example, has approximately 10,000,000 seeds to the pound; alfalfa--250,000, and alsike clover--700,000.

Of the many seed cleaning machines, there is one unit that has become basic and is found in all cleaning plants, large or small. This is the air-screen machine which, almost without exception, performs the first operation in any seed cleaning sequence. Other machines, such as the length separator, spiral, gravity machine, velvet roll unit, debearder, and magnetic separator, are finishing machines designed to make a specific separation.

The particular combination of units forming a seed processing line will be dictated by the seed crops and contaminants being handled. Figure 1 indicates a typical flow diagram for a corn processing plant, and Figure 2 represents the general sequence of operation in cleaning several other common crops.

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* Head of Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A.R.S., U.S.D.A.

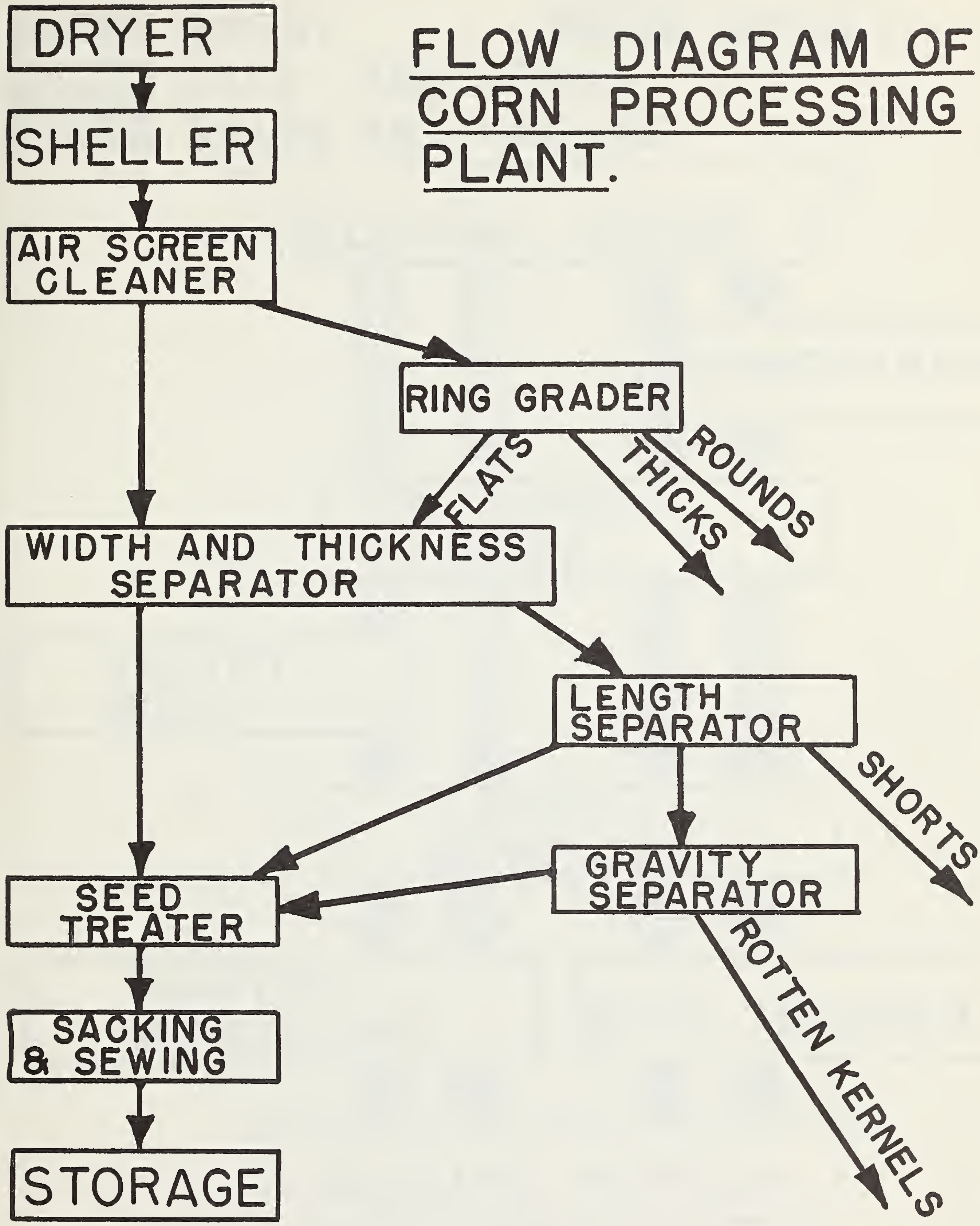
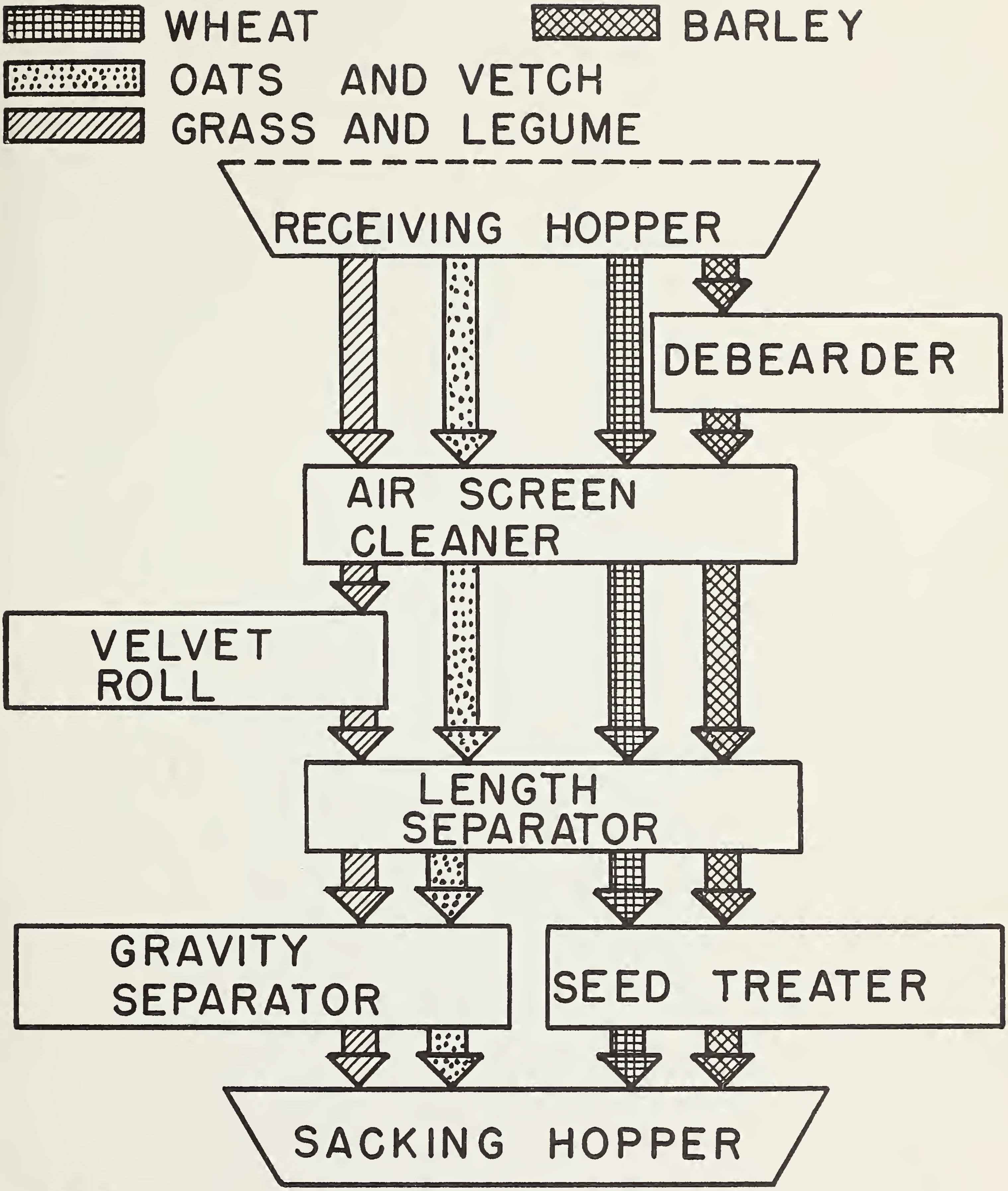

FLOW DIAGRAM OF CORN PROCESSING PLANT.
DRYER
SHELLER
AIR SCREEN CLEANER
RING GRADER
FLATS
THICKS
ROUNDS
WIDTH AND THICKNESS SEPARATOR
LENGTH SEPARATOR
SHORTS
GRAVITY SEPARATOR
ROTTEN KERNELS
SEED TREATER
SACKING & SEWING
STORAGE

FIG. 1



STEPS IN SEED CLEANING.

FIG. 2

AIR-SCREEN SEED CLEANER
by
Leonard M. Klein*

Principle of Operation

The air-screen cleaner is one of many seed cleaning machines that make separations on the basis of difference in physical properties of seed. The properties involved with the air-screen cleaner are size, shape, and density. Screens with holes of various size and shape are used to make a size and shape separation. The density of a seed determines whether it will be carried by or dropped out of an air stream.

Description

The air-screen cleaner is the basic machine in all seed cleaning plants. Size of the machine varies from small models with two screens and only one air column to large industrial type machines with four or six screens and several air columns. The most common units have a seed hopper equipped with a metering device which feeds seed into an air stream. The heavier seed drops through the air stream onto the first of several screens. The oscillating screens clean and grade the seed by eliminating material larger and smaller than the crop seed being cleaned. The last screen feeds the graded seed into a second air separation where more light material is removed.

Adjustments

The feed rate may be varied by changing the fluted metering roller speed or by adjusting the metering gate opening. Rate of air flow may be varied by fan dampers to pick up more or less of the light material. Screens of different size and shape openings may be selected. The slope of the screen and the rate of oscillation may be varied. See Figure 3. The screens may be used in several combinations. The first screen is always a "top" screen or one that will let the crop seed pass through and scalp off large foreign material such as sticks, chaff and other larger undesirable seeds. The last screen is always a "bottom" screen or one that will retain the crop seed and reject the small foreign material such as dirt and other smaller undesirable seeds by letting them drop through. The intermediate screens may be used as

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* Agricultural Engineer, Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A.R.S., U.S.D.A.

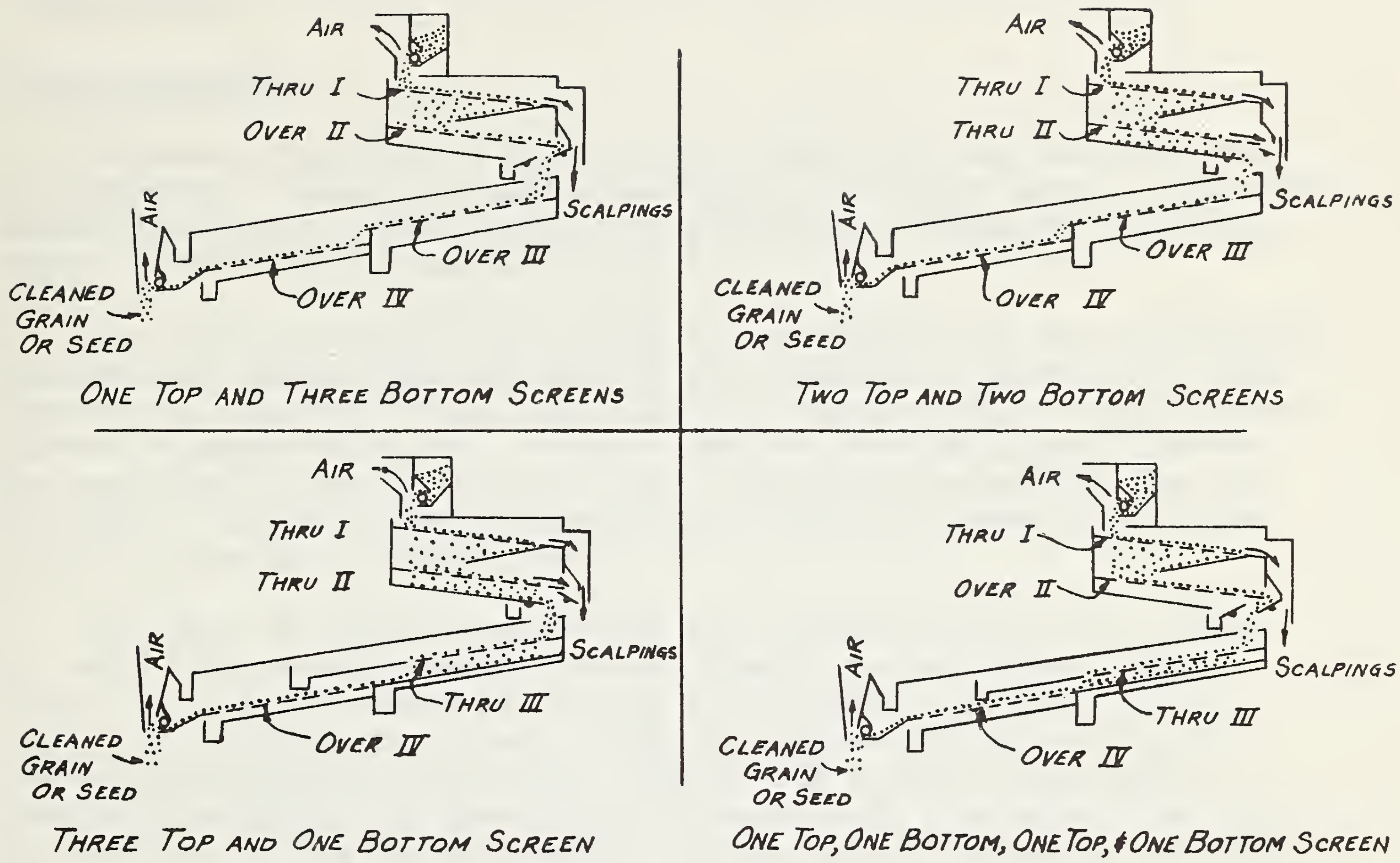
AIR
THRU I
OVER II
SCALPINGS
AIR
OVER III
OVER IV
CLEANED GRAIN OR SEED
ONE TOP AND THREE BOTTOM SCREENS
AIR
THRU I
THRU II
SCALPINGS
AIR
OVER III
OVER IV
CLEANED GRAIN OR SEED
TWO TOP AND TWO BOTTOM SCREENS
AIR
THRU I
THRU II
SCALPINGS
AIR
THRU III
OVER IV
CLEANED GRAIN OR SEED
THREE TOP AND ONE BOTTOM SCREEN
AIR
THRU I
OVER II
SCALPINGS
AIR
THRU III
OVER IV
CLEANED GRAIN OR SEED
ONE TOP, ONE BOTTOM, ONE TOP, & ONE BOTTOM SCREEN

FIG. 3

either top or bottom screens thus giving several possible screen combinations.

Screen Selection

Screens of perforated metal or woven wire mesh are commonly used in air-screen cleaners to make separations by size and shape. Perforated metal holes may be round, oblong, or triangular. Woven wire mesh may present square or rectangular openings.

The size of a round hole screen is the diameter of the perforation. Perforations larger than the size 5½ are measured in 64ths of an inch. Therefore, a one inch round hole screen is numbered 64, a one-half inch screen is numbered 32, etc. Screens smaller than 5½/64 inch diameter are measured in fractions of an inch. The next size smaller than 5½ is 1/12. A 1/25 is usually the smallest perforated round hole screen available except by special order.

The size of oblong hole screens are measured by the same system as round hole screens except that two dimensions are given. Large oblong or slotted screens have their width measured in 64ths of an inch. For example, the size 9 x 3/4 is a screen with an oblong hole measuring 9/64 inch by 3/4 inch. Oblong hole screens with widths smaller than 5½/64 inch generally are measured in fractions of an inch. For example, 1/18 x 1/2 is a screen with an oblong hole measuring 1/18 inch by 1/2 inch. There are some exceptions to this small oblong hole numbering system. For example, 3½/64 x 7/8 or 4-3/4/64 x 3/4. In all cases, the final number is the length of the slot.

Triangular hole perforations are usually measured by the length of each side of the triangle in 64ths of an inch. The three sides of an 11 triangle hole screen measure 11/64 inch. Another less common system is to designate the size of the triangle by the diameter in 64ths of an inch of the largest circle that can be inscribed within the triangle.

Wire mesh screens are designated according to the number of openings per inch in each direction. A 14 x 14 screen has 14 openings per inch in each direction. The size 6 x 32 has 32 openings per inch across the screen and 6 openings per inch down the screen. Wire mesh screens such as 6 x 32 present rectangular shaped openings equivalent to the openings in oblong hole perforated screens.

For cleaning round shaped seeds, the two basic screens are round hole top screen and a slotted hole bottom screen. The round hole top screen drops round seed through the closest-fitting hole that it will go through and screens off anything that is larger. The slotted hole bottom screen has narrow slots which hold the round seed but drop the split or broken crop seed and many weed seed.

For cleaning elongated seeds, such as oats and fescue, the two basic screens are a slotted top screen and a slotted bottom screen.

The basic screens for cleaning lens shaped seeds, such as flax and lentils, are generally a slotted top screen and a round hole bottom screen. The lens shaped seed will turn on edge and drop through a slotted top screen but lie flat and pass over a large round hole bottom screen while most weed and other crop seed will pass through. For a slick shiny seed such as flax, a wire mesh screen with rectangular openings can be used to make the same separation as an oblong perforated screen only with greater capacity. The rough wire surface causes the slick flax seed to turn on edge more readily, and there are more openings per square inch of screen area.

Triangular hole perforated screens make separations because of differences in shape between crop seed and weed seed. Triangularly shaped weed seed will drop through openings that long crop seed will float over.

The percentage open area of screens varies with different types. Wire mesh screens have more openings per square inch and therefore more open area than perforated metal screens with openings of equal size. For that reason wire mesh makes better bottom screens for small seeds and permits higher capacities with the same accuracy than do perforated metal screens.

Another reason for selecting wire mesh screens as bottom screens is that the rough surface agitates the seed presenting each face to the openings of the screen.

When selecting a slotted screen, the length of slot should be considered. The slot should be long enough for the seed dropping through to pass freely, yet short enough that the retained seed will not be screened too heavily. Shorter slots retain their shape longer and give longer screen life.

Screen Pitch

The slope of each screen may be adjusted independently. A steep screen tends to make a closer separation, just as though a smaller size screen were used, as well as move seed more rapidly, increasing capacity. Top screens are usually set at a steeper slope to assist in scalping off stems and trash. Bottom screens are usually set at a flat pitch to give small undesirable seed and trash sufficient time to drop through.

Screen Rate of Oscillation

The rate of screen oscillation should be selected to best suit the material being handled. The rate should be fast enough to spread and

move the material across the screen, but not so fast that it tends to bounce the seed and lessen its chances of dropping through the screen openings. However, a fast oscillation, just as using a steeper pitch screen or as using a smaller hole screen, may be used advantageously to effect a closer separation.

Screen Brushes

Most modern air-screen cleaners are equipped with adjustable self-powered screen-cleaning brushes which operate continuously when the machine is in operation. The brushes move against the lower side of the screens and keep the holes free of lodged seed.

Screen Bumpers

Another method of freeing screens of lodged seed is the mechanical bumper that periodically gives the screen a thump at its top center point bouncing seed from the screen openings. This method is especially useful with long seeds such as grass that tend to resist the action of brushes.

Air Flow Rate

As the mixture falls to the first scalping screen from the seed hopper, it must pass through the upper air suction which removes much of the light chaff and dust. The seed dropping from the last bottom screen, falls through the lower air suction which removes light seed and trash not removed by the upper air and screens. Both air blasts are usually regulated by an adjustable vane or damper and should be strong enough to remove a few good seed along with the trash.

Auxiliary Methods and Equipment

Screen dams are objects fastened to bottom screens to provide more accurate screening than usual. The smooth flow of the seed over the screens is interrupted momentarily causing them to be thoroughly sifted. Such a screen dam is especially useful in separations of small round seed.

A device that can be used to improve the separation of a top screen is a piece of oil cloth draped over the screen with the slick side down and lying flat on the screen. The weight of the oil cloth tends to hold the long pieces of straw and stems flat on the screen so that they cannot turn on end and go through the screen.

Another device to improve the separations of a top screen is to blank off the lower section. Once a point has been determined where all good seed have dropped through, the screen below that point may be

blanked off. In that way, any foreign material passing over the unused lower portion of the top screen will have no further chance to turn on end and drop through.

Clod-crushing rolls may be employed to help make separations of seed from clods. Usually two rubber-covered rolls pressed together by spring tension are located to receive the seed and clods after their initial scalping. Rubber rolls smash the clods while leaving the seed uninjured, then lower screens remove the dust from the seed.

THE SPECIFIC GRAVITY SEPARATOR

by
Norman R. Brandenburg*

Specific gravity separators employed in the seed cleaning industry are adaptations of a device known as a "dry concentrator" used for ore processing in arid mining areas. The term "specific gravity separation" is often contracted to "gravity separation," and refers to a method of segregating particles having the same size but different specific gravity.

In operation, a controlled air stream is forced up through a perforated, inclined deck which has a reciprocating motion. Seed enters the deck at the rear end and flows toward the front where discharge takes place. As the seed mass moves forward, it is partially suspended above the deck in the air stream which is regulated to float the light seed, while heavier particles sink to the deck surface. Heavy particles tend to move "uphill" because of contact with the deck surface which, through its oscillatory motion, "bounces" them to the high side of the deck. Due to the deck pitch, light particles migrate to the low side of the discharge edge.

Parts of the Machine

The blower: Air is forced into a compartment called the air chest. Here, the air is distributed evenly under the deck by an arrangement of air baffles. Dampers, usually placed at the blower intake, govern the amount of air flowing into the air chest.

The feed: Satisfactory operation of the machine depends upon proper feed rate. Rate at which seed enters the machine should be regulated so that the deck is always covered.

The deck: Feed enters the machine at the rear surface of the table or deck. Separation takes place as the seed mass moves forward along the deck. Deck material is selected from many kinds of fabrics, woven wire meshes, perforated metal and other substances so that a complete range of seed sizes can be accommodated. The purpose of the deck is to give support to the seed mass while allowing a uniform air flow.

The eccentric drive: The machine is equipped with a variable eccentric drive to provide oscillatory deck actions of the intensity required to give the desired movement of seed across the deck.

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* Agricultural Engineer, Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A.R.S., U.S.D.A.

The side tilt: A vertical adjustment is provided to regulate deck pitch longitudinally (this tips the deck toward the front or discharge edge.) Specific gravity of particles in the mixture dictate the side tilt required. In general, a seed mixture with components having little difference in specific gravity requires a relatively flat side-tilt adjustment to allow stock a longer exposure time on the deck.

The end raise: A vertical adjustment is also provided to regulate deck pitch laterally (this tips the deck toward the left.) With this feature, heavier elements in the mixture are caused to travel "uphill." End raise, together with side tilt, encourages lighter material floating on top of the seed bed to flow across the deck diagonally to the light end of the discharge edge.

When to Use the Gravity Separator

There are three rules limiting the use of this machine which should be kept in mind:

Rule 1: Particles of the same size but of different specific gravity can be separated. As an example, consider a seed lot that has been previously graded to a uniform size. In this lot there may be undesirable seeds having a light weight due to disease or blight. The weight difference may be the only physical characteristic permitting separation. As the material moves across the gravity deck, each inch of the discharge edge cuts out a different test weight. The lightest material will be discharged at the lower part of the deck with progressively heavier seeds being discharged toward the right or higher portion.

Rule 2: Particles of the same specific gravity but of different size can be separated. Here the gravity machine acts as a size grader, because it separates such a mixture according to difference in size of particles. For instance, consider a lot of clean clover seed with all particles of essentially the same specific gravity. Running this product over the gravity deck will result in a grading by size. Smaller seeds will report to the lower part of the discharge edge, with progressively larger seeds being discharged at the upper edge.

Rule 3: Particles differing in size and also in specific gravity cannot be separated efficiently. Rule 3 is an extension of Rules 1 and 2. The proper use of the gravity machine must be limited to a mixture as described in Rule 1 or sometimes Rule 2, but not a combination of both. An example of a mixture described in Rule 3 is wheat mixed with oats. These components differ in size and also in specific gravity. If this mixture were to pass over the deck of a gravity machine, the distribution of material at the discharge edge would be similar to that shown in Figure 4.

DISTRIBUTION OF OATS AND WHEAT ON GRAVITY TABLE

FIG. 4

The gravity machine operating on such a mixture will produce three fractions: (1) a small but clean fraction of light oats, (2) a large middling fraction of heavier oats and light wheat, (3) a small but clean fraction of heavy wheat. If the middling fraction were returned to the gravity machine and re-run, no additional separation would be made.

If the above mixture had been sized initially by screening, a better separation would have been obtained with the gravity machine. Gravity separations of each sized fraction would result in a smaller total middling product, since more of the mixture was put into a classification covered by Rule 1 ("particles of similar size but of different specific gravity can be separated.")

The mixture of wheat and oats is used here only as an illustration. Separation of wheat from oats is normally made by a machine designed to separate by length difference.

Seed mixture types: The gravity machine should be used only on mixtures which are described by Rule 1. Whether the mixture meets Rule 1 in its natural condition, or meets Rule 1 only after being subjected to a screening or a size-splitting treatment, will depend on the seed lot. Commodities included in Rule 2 can normally be best separated by a size grading device such as an air-screen machine. Mixtures as described by Rule 3 require initial treatment to make them approximate Rule 1.

The Deck

The deck might well be called the "heart" of the gravity machine. Deck fabric, itself, plays an important role, and separation efficiency is also dependent on various adjustments of the deck. No one deck material has proven effective for a wide range of seed sizes--usually about three or four decks are needed.

The main job of the deck fabric is to assist in stratification of seed material above the deck, yet adequately restrict air flow to build up static pressure within the air-chest and insure uniform air distribution. Open meshed wire screen is not satisfactory, because air travels along paths of least resistance, and would not flow sufficiently through deck sections remote from the blower or those having a deeper seed bed.

Particles of small size can be handled on cloth decks of low porosity which pass smaller quantities of air. On the other hand, particles of larger size require a more permeable or open deck capable of passing larger quantities of air needed for stratification.

Adjustments

Feed rate adjustment: The rate of material entering the gravity deck is critical. The machine will not operate efficiently with too light a feed rate nor with a feed rate that is too heavy. Optimum rates vary according to the difference in specific gravities existing between the two or more commodities on the deck.

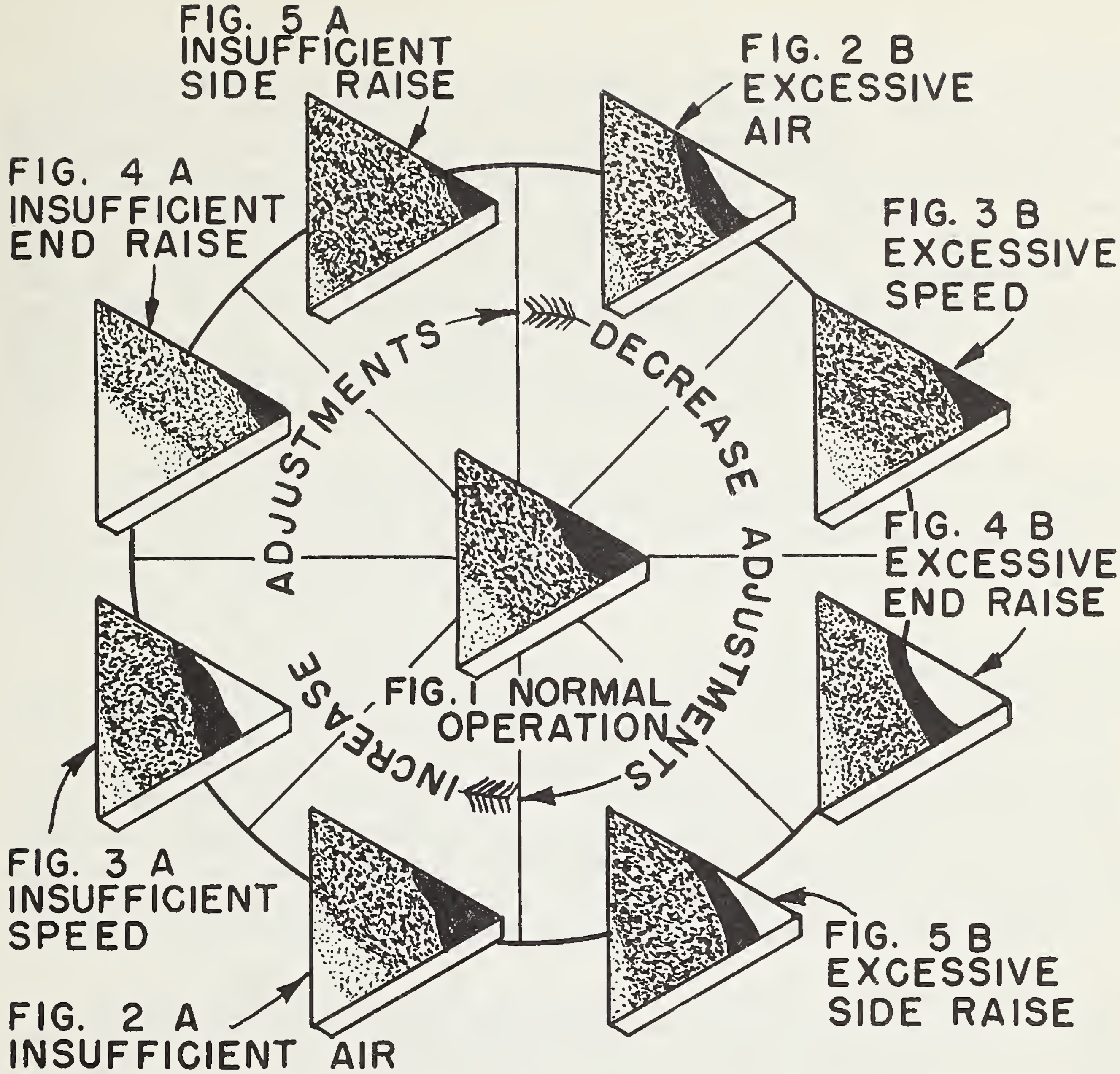
The greater the difference in specific gravities, the more rapid will be the travel of light material to the low side of the deck and the subsequent reporting of heavy material to the high rail. Greater feed rates are then allowable with this type of mixture. Conversely, when separating a mixture with small differences in specific gravity, lateral motion of the seed material is not as pronounced, and feed rates must be reduced.

Insufficient feed rate causes seed to travel across the deck in a thin bed, and portions of the deck will be blank. For satisfactory separation, the deck surface should be covered at all times the machine operates. An excess rate of feed will "rush" the procedure and too many good seeds will be discharged with the middlings or rejects.

Air adjustment: The air stream through the porous deck prevents light seed from touching the deck while it "floats" to the low side. The air is regulated to permit heavy seed to contact the oscillating deck. The accelerated sideways motion of the deck imparts an uphill direction to the seed. See Figure 5.

A common misadjustment is an over-supply of air through the deck. If this is the case, the intense air stream acts as a mixing agent, rather than a separating means, and formation of horizontal layers or strata does not take place. The basic principle of successful gravity operation consists of stratifying the particles into layers of different weights, and then separating the layers by combination of eccentric motion and inclination of the deck. These actions take place in two zones on the deck: (1) the stratifying area (2) and the separating area.

As the seed lot flows from the feeder to the deck, the seed particles immediately encounter thousands of small air jets caused by compressed air from the air chest being forced through openings of the porous deck material. The size of the stratifying area at the rear of the deck depends on the existing differences in specific gravity of the seed particles. The greater the difference in specific gravity, the smaller will be the area required for stratification. Seed particle motion in the stratifying area can be considered essentially vertical, in results in a stratified seed mass with light material "floating" on top, and heavy material partially suspended just above the deck surface.



A. START THE SEPARATION AND WAIT FOR THE MATERIAL TO DEFINE A CONSTANT PATTERN OF DISTRIBUTION.

B. COMPARE EACH PATTERN OF MATERIAL DISTRIBUTION WITH FIG. I FOR IDEAL OR OPTIMUM ADJUSTMENTS.

C. CORRECT ERRORS OF ADJUSTMENT IN THE FOLLOWING ORDER.

1. AIR ADJUSTMENT FIG. 2 A OR 2 B
2. ECCENTRIC SPEED FIG. 3A OR 3B
3. END RAISE SLOPE FIG. 4A OR 4B
4. SIDE RAISE SLOPE FIG. 5A OR 5B

ADJUSTMENT CHECK CHART

FIG. 5

The remaining portion of the deck is the separating area. Here, motion of the seed particles is confined generally to certain layers, the direction of motion being essentially horizontal. The lifting action of the air stream still must be maintained at a degree sufficient to retain the formerly established stratification. However, as the seed particles proceed on their journey to the front or discharge edge of the machine, the stratification becomes less pronounced. Movement of lighter particles to the low side of the deck and heavier particles to the high side of the deck begins to appear. The separation becomes complete when the vertical stratification has dissipated and given way to a horizontal gradation of material as it flows off the deck.

Excessive air rate tends to shift the seed material on the deck to the low rail and produce uncovered areas at the upper rail. Insufficient air rate shifts the seed material to the high rail with uncovered areas appearing at the lower rail. Satisfactory operation requires uniform coverage of the deck at all times.

Side tilt adjustment of the deck: The side tilt adjustment depends upon the area required for the stratifying. The greater the difference in specific gravity of the seed components, the smaller will be the required stratification area and the steeper may be the side tilt of the deck. Conversely, flatter side tilt adjustment is required for seed mixtures having more similar specific gravities. Capacity of the gravity machine is directly related to the side tilt, therefore the most efficient operation involves the maximum side tilt setting that still permits the mixture enough time on the deck to become separated. See Figure 5.

End raise adjustment of the deck: Increasing end raise (or lateral adjustment) causes more material to flow toward the low side of the discharge edge, and flattening the raise moves material to the high side. The maximum slope of the discharge edge is usually about 6^{o} from the horizontal, but a 2^{o} figure is most common for the average seed mixture. See Figure 5.

Eccentric speed adjustment: Heavier materials of the seed mixture are forced to travel uphill due to motion induced by the eccentrics. This uphill travel is caused by the inclination of the toggles supporting the deck, which are activated by the eccentric thrust. The deck is given a lateral, and sometimes a longitudinal, motion as well as an upward and downward motion which moves seed in the direction of the deck travel. The deck surface then drops from the seed bed and again contacts it on the next forward stroke. Heavy seed particles "hop" across the surface of the deck at a rate governed by the various machine adjustments. Eccentric speed is one of the adjustments controlling the motion of the seed. See Figure 5.

An increase in eccentric speed will cause the material to travel faster towards the high part of the deck. A decrease in eccentric speed will cause a slower travel to the high part, and must be used for those mixtures whose components do not have much difference in specific gravity.

Operation Checks

All five machine adjustments are closely inter-related and must be blended together to obtain optimum separating conditions. In addition to the described adjustments, there are several precautions that should be observed in machine installation and maintenance.

1. Blower direction: The blower fan will develop insufficient pressure if running backwards. Three-phase motor rotation may be reversed by interchanging any two of the motor wire connections.

2. Weak foundation: A weak foundation will result in "secondary" vibrations within the machine which may counteract the desired eccentric vibration. Poor separation of seed material on the deck then results. The machine requires a good solid foundation.

3. Clean air: If clean air is not available within the installation room, air should be ducted in from an outside source. Dust-laden air soon plugs the openings in the deck cover.

4. Belts and clamps: All drive belts require periodic checking to maintain adequate tension. Loose clamps on the machine will set up secondary vibrations.

SEED SEPARATION BY LENGTH

by
Elmon E. Yoder*

THE DISC SEPARATOR

The disc separator is generally used to effect a special separation after an initial separation by an air-screen machine, or to make a complete separation by itself. This machine is a length-sizing device which lifts under-length material out of a mixture of seed. Disc separation is not affected by seed coat texture, density, or moisture content to any great extent.

The disc separator consists of a series of indented discs which revolve together on a horizontal shaft. Each disc contains numerous indented undercut resesses on each face. See Figure 6. As the discs revolve, the recessed pockets lift out the short seed and reject the longer seed.

In a normal arrangement the discs are so located that disc pocket size increases progressively from intake end to discharge end. The smallest particles are removed first, with progressively larger liftings being made as the seed mass moves toward the discharge end.

Seed Travel

The center of the disc is open. Seed travel from intake end of the machine to discharge end is provided by vanes attached to the spokes of the disc. The removable vanes act like a screw conveyor to move the mass of seeds slowly through the open portion of the discs. The seed mass must pass through the open portion of each disc in order to reach the tail end of the machine. As the seed mass moves along, it is brought in contact with each disc so that succeedingly larger size materials may be removed. The spokes and conveying vanes also stir and agitate the seed mixture, preventing any stratification within the machine.

The body of the machine is constructed to fit close to the rims of the battery of revolving discs, but with sufficient spacing to prevent the crushing of seed. This encourages all seed travel to be through the center and open portion of the discs only.

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* Agricultural Engineer, Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A. R. S., U. S. D. A.

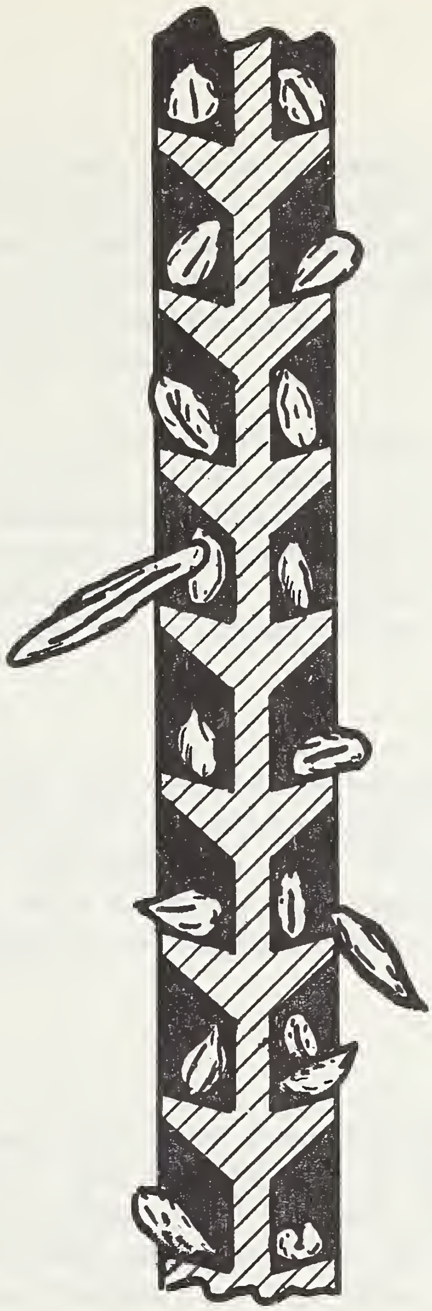

FIG. 6 CROSS SECTION OF INDENT DISC

Disc Pocket Design

The disc pocket functions like an elevator bucket. Seed which will fit into the pocket as it passes through the reservoir of seed at the bottom of the machine is held in the pocket by combination of centrifugal force and ability to become seated on the bottom of the pocket. Seed is discharged from the pocket in the same manner as an elevator bucket relieves its load.

Disc pockets are made in two basic shapes, with each shape available in a number of sizes. Disc size is indicated by its pocket width in a millimeters, measured radially from the center of the disc. Length or height of the pocket is essentially the same dimension as the width. Depth is usually one-half the dimension of the width. The undercut part of the pocket is referred to as the bottom.

The "R" Pocket

The "R" pocket derives its name from "rice". It was designed to remove broken rice grains from the whole grains. The pocket looks like an inverted "V". The lifting edge is flat while the leading edge is round. Pocket design is such that it will reject round seeds; but will lift out cross-broken grain or elongated seeds since they have a flat surface to bear on.

The "V" Pocket

The "V" pocket derives its name from "vetch". It is designed to remove round shaped seeds. The pocket has a round lifting edge and horizontal or flat leading edge. "V" pockets tend to reject tubular, cylindrical or elongated seeds as they have no flat surface to sit on. These seeds tip out of the pockets as the disc revolves.

Both the "V" and "R" pockets are made only in the smaller sizes. Normally, sizes are limited to $2\frac{1}{2}$ mm to as large as 6 mm. These discs are designed primarily for removing small materials from a mixture. The letters "V" and "R" are always followed by a number, such as V3, R4$\frac{1}{2}$, V5, etc. The numeral indicates the size in millimeters. As an example, a R5 is a flat lifting edge pocket with a radial width of 5 mm.

Other Designations

Some discs are made having pockets designated solely by alphabetical notation. They carry no numeral to indicate width or size. Normally these pockets are square faced and are used in specialized separations or splittings. These pockets are usually made only in sizes exceeding 1/4" in radial width.

OPERATION OF THE DISC SEPARATOR

Disc Rotational Velocity

The speed at which the discs rotate is held nearly constant. Variations of only a few rpm from normal affect the the efficiency of the disc pockets. Too great a velocity prevents the material from becoming "seated" in the bottom of a pocket, or prevents the discs from discharging that seed previously picked up. A too-slow velocity does not provide sufficient centrifugal force to hold seed in the pocket.

Disc Pocket Size

Whether the disc separator operates with all discs of the same size pockets, or with a combination of pocket sizes and types depends upon how close the seed mixture has been previously graded. In a combination type arrangement, the discs are grouped into sections with the smaller sized pocket discs installed near the seed intake. In this arrangement, material both shorter and longer than the seed being cleaned can be removed. The selection of "V" pockets, "R" pockets, or a combination of each depends upon the shape characteristics of the seed and the grading desired.

Reject and Re-run

Flexibility of operation can be achieved by provision for re-run or removal of such fractions as may be desired.

Seed Travel Adjustment

Conveyor vanes may be removed or added in whatever quantity desired to make the seed mass travel through the machine at a rate giving best separation. The capacity and efficiency is determined by the ratic of number of small particles to be removed to the number of pocket recesses to remove the material. The travel speed of the seed mass may be controlled accordingly. Raising the tailings gate tends to keep the seed in the machine longer and gives the discs more time to clean the seed throroughly.

THE INDENTED CYLINDER SEPARATOR

The indented cylinder separator consists of a rotating horizontal cylinder and a movable horizontal separating trough. The inside surface of the cylinder has closely spaced small semi-spherical indents. A seed mass lies on the bottom of the cylinder. As the cylinder rotates on its axis, the shorter seed in the seed mass is lifted from the mixture by the numerous indents. At some point before reaching the top of the arc of rotation the seed drops from the indents and is received by an adjustable trough. See Figure 7.

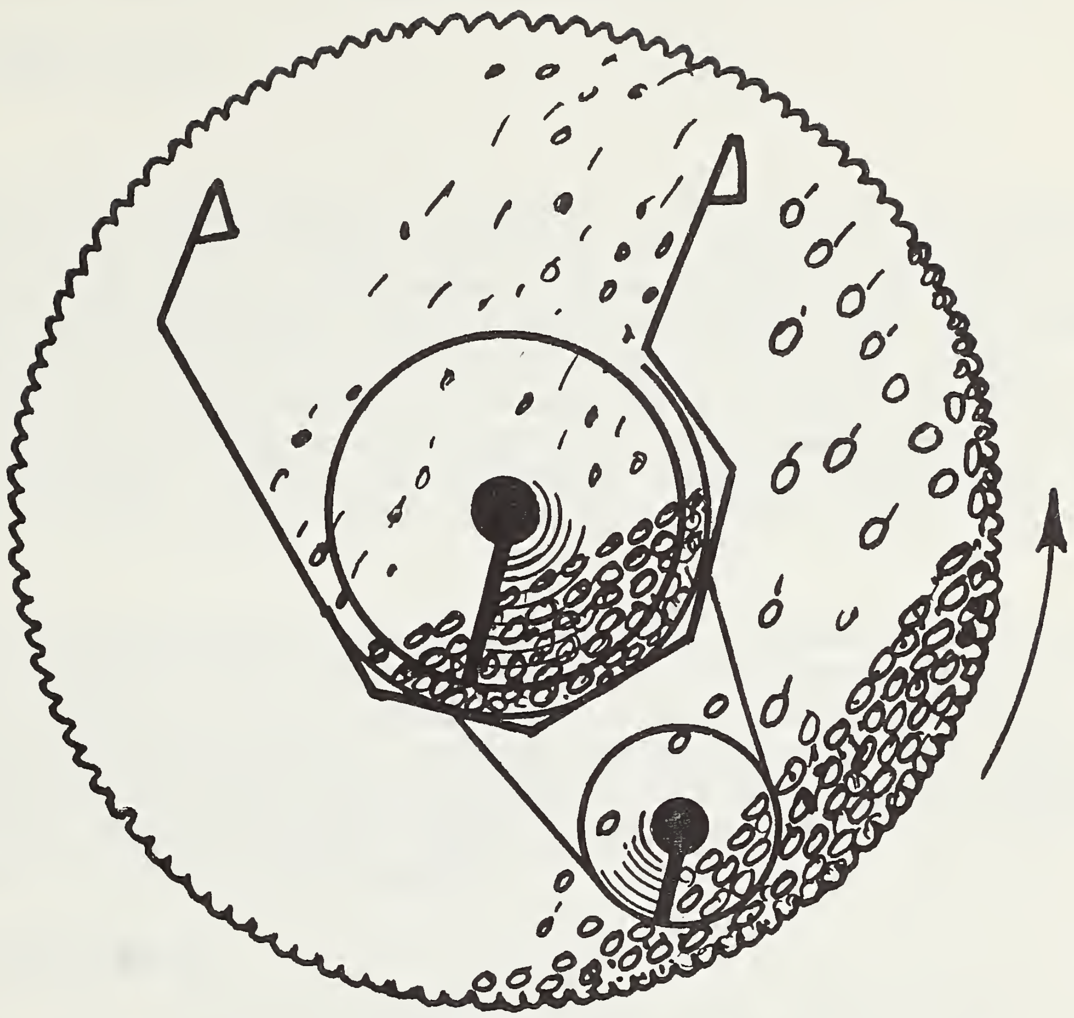

FIG. 7 CROSS SECTION OF INDENT CYLINDER SEPARATOR

Indented cylinders perform separations on the same basis as the disc separator. Both separate on a basis of length difference. Both lift the under-length material from a seed mass, making a length sizing separation.

INDENT POCKET DESIGN

Shapes

There are various shapes of indents. The shape of the bottoms and sides, the slope angle of the sides, and the depth of the indent in relation to width give a wide range of indent shapes each with its own separation characteristics. For example, an indent with cone shaped sides is preferred for the removal of seeds which do not roll readily. A cylinder having spherical shaped indents drawn slightly shallower than their diameter is preferred for removal of round seeds such as crimson clover or soybeans. Indents with straight vertical sides would be very positive in lifting action but allow only a limited flexibility in operation.

It is not practical to install more than one size or shape of indent in any one cylinder. Nor is it practical for the operator to change indent cylinders to take out each shape or size seed separately. A compromise in pocket design is reached where design of side slope, depth, width and shape provides the most good for the most seeds normally encountered. Indent size has numerical notation, with the larger numbers indicating the larger size indents.

Selecting the Indent

Indent size should be selected by using the smallest size indent which satisfactorily lifts the longest material to be lifted. The combination of centrifugal force and indent size lifts the shortest particles and carries them the farthest out of the main seed mass. Next to fall from the indent are the intermediate size seeds. The longest seeds fall out of the indents only a short distance above the seed mass, or are not lifted at all.

Some materials are too large to lift, and may roll along like a rope in the bottom of the cylinder. Stratification of the seed mass results. To prevent this stratification, separators are equipped with a screw conveyor or similar device which runs through the machine. This also acts as a seed leveling device. If some method of leveling the seed were not used, the seed mass would tend to build up at the head end of the cylinder. If this were allowed to happen, the seed level at the head end would become so high that material would fall into the trough at that end due to sheer volume.

At the feed end of the cylinder there are large numbers of the undersize particles in the seed mass. These quickly find their way into the indent pockets, even being taken out by multiples. As these sizes are depleted and the mass works its way toward the center of the cylinder the intermediate size material is removed. At the tail end of the machine the final and closest grading by the indent is made.

OPERATION OF THE INDENT SEPARATOR

A particle is lifted by the indent from the seed mass by a combination of centrifugal force and the retention of the particle in the indent due to indent conformation. Unlike the disc separator, seed coat texture, density and moisture content of the seed do affect separation in an indent cylinder. Two adjustments give the machine extreme flexibility. Variation of seed physical properties supplement these two adjustments to give a wide range of separation response.

Speed of Cylinder

Centrifugal force is the primary separating agent of the indent cylinder. A particle is held in the indent recess by centrifugal force sufficient to lift it from the seed mass, and to hold it until some determined point of the travel arc is reached. Adjustment for cylinder speed is provided on this machine. Speed should not be increased beyond an amount to carry seed in the indent to a point directly over the axis of the cylinder. Speeds in excess of this will not allow the seed to be released from the indent, and would carry the seed to again re-enter the seed mass. Speed must be great engouh to lift the seed from the mass. Between these two extremes of speed, maximum separation efficiency can be obtained.

The indent cylinder is most efficient for lifting material having weights exceeding 45 pounds per bushel. For this reason the cylinder is more practical in the lifting of small grains, legumes, etc. than it is for lifting grasses.

Friction of the seed in slipping out of the indent affects the distance it will travel in the indent pocket before being dropped. Hence a wet seed will be lifted and carried from the seed mass more readily than will a slick dry one.

Adjustment of Liftings Trough

The edge of the liftings trough can be set at any position giving best separation. Faster cylinder speeds require higher trough position. The many combinations of cylinder speed and trough positions gives considerable flexibility in operation.

METHODS OF USE

Use in Combination

To make a cleaning job more complete in one process, this separating device has been combined into one machine offering other mediums of cleaning. For example, equipment is made which offer operations of scalping, aspiration, disc separation and indent cylinder separation in one machine.

Use of Multiple-Cylinder Units

A useful multiple-cylinder unit can be made with cylinders in combination. The cylinders are grouped vertically, with the top cylinder provided with the middle sized indent. Liftings of the top cylinder are sent to a cylinder below equipped with the small indent. Tailings of the top cylinder are sent to a cylinder below equipped with the largest size indent. In others words, the top cylinder is a "splitter". The final separations of each fraction are made in the two bottom cylinders.

PNEUMATIC SEPARATORS

by
Jesse E. Harmond*

There are at least a dozen manufacturers of pneumatic separators for seed processing. Some units are called aspirators and others pneumatic separators, but all use the movement of air to divide materials according to their terminal velocities. The primary difference in the two types is the location of the fan. On the aspirator, the fan is placed on the discharge where it creates a vacuum so that the atmospheric pressure can force air through the separator. In the pneumatic separator, the fan is on the intake end where it creates a pressure in excess of atmospheric pressure thereby forcing air up through the separator.

The air velocity through the separators can be accurately adjusted to the terminal velocity of the material to be moved by opening or closing the fan air intake.

Figure 8 is a cross-section of an aspirator-scalper. The seeds are fed from the hopper "A" and run through the rotating scalping screen "C" which allows the seed to pass through to the aspirating chamber "E" while sticks, straw, leaves, and other large roughage are carried over the revolving screen into section "B". With a suction or negative pressure at "H", air is drawn through aspirating chamber "E" at a velocity slightly below the terminal velocity of the heavy plump seed. The shriveled or weevil-eaten seed and lighter trash and weed seeds are lifted and deposited into chamber "F", and the air escapes through chamber "H". The heavy plump seed fall through the incoming air and out the inlet into a conveyor or seed bin. The air velocity through the aspirator is controlled by proportioning the by pass air through "M" with adjustable gate "O".

When material is fed into the separator, all products will be lifted whose terminal velocities are equal to or less than the velocity of the air movement through the machine. Material with a higher terminal velocity will fall against the air flow and out the bottom of the air column.

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* Head of Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A. R. S., U. S. D. A.

SCALPING ASPIRATOR

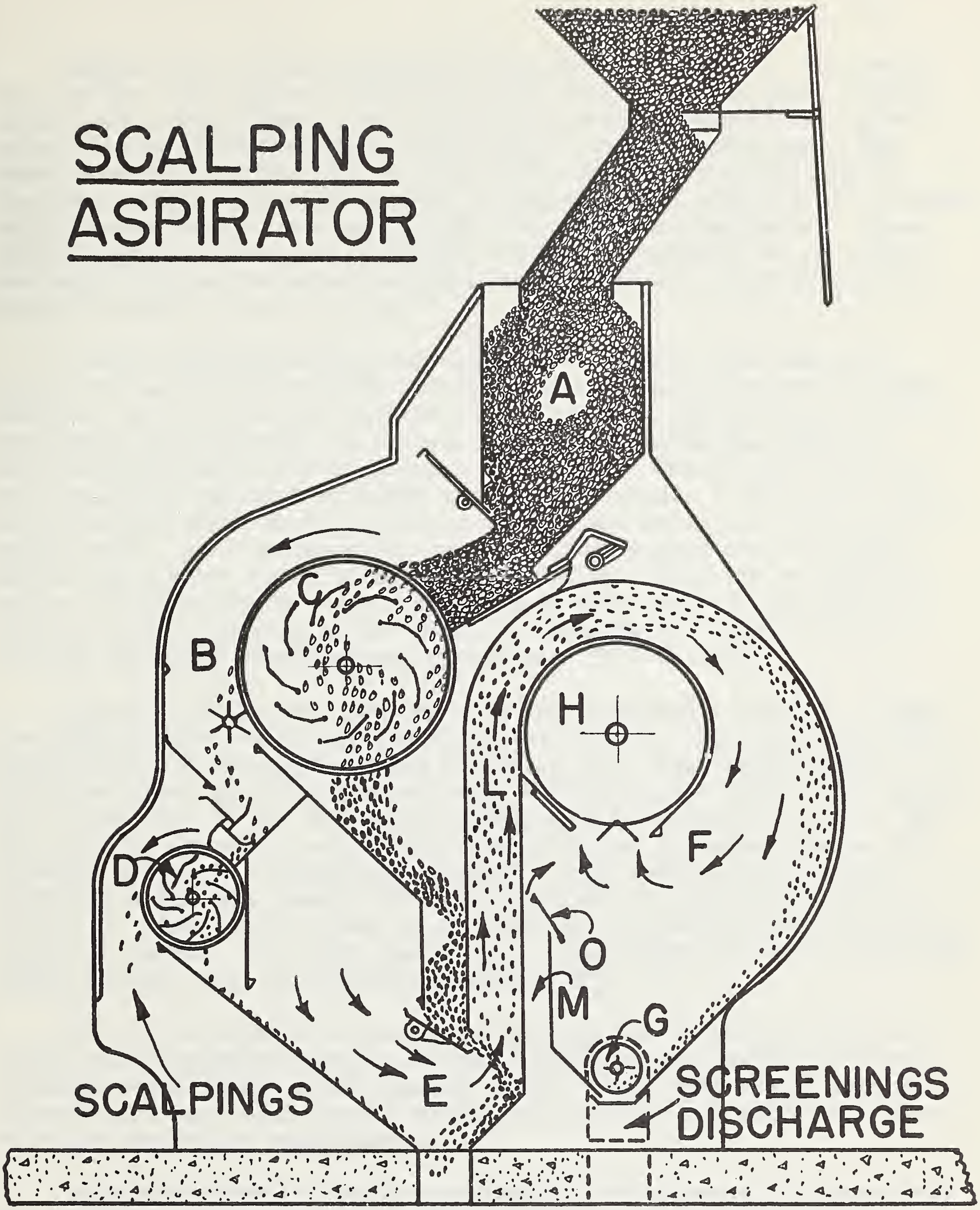


FIG. 8

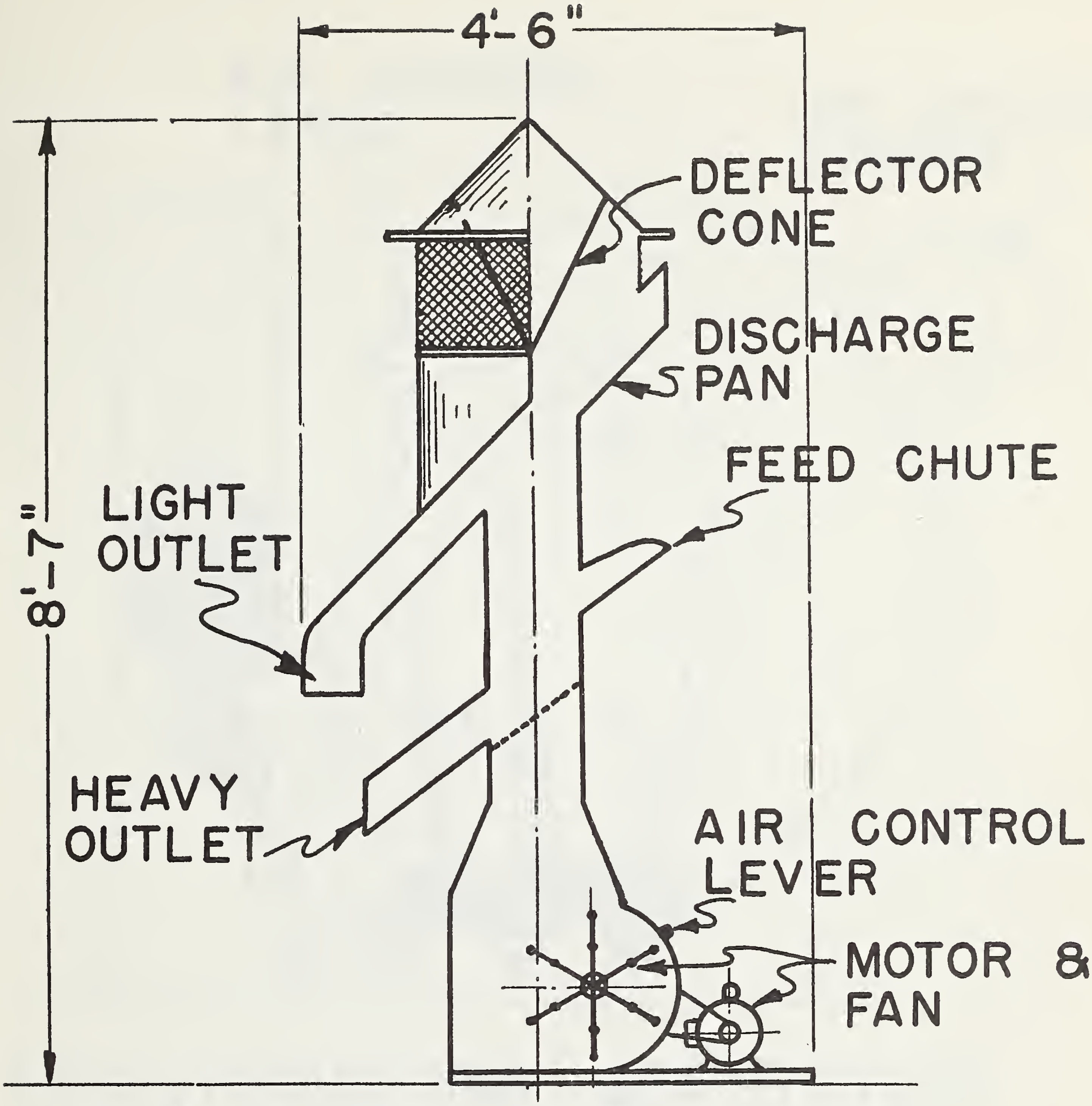
Figure 9 is a cross-section of a pneumatic separator. The seeds are fed into this chute. The light seed, splits, broken seed, chaff, straw, etc., are lifted by the air being forced up through the column where they are diverted by this cone out to the discharge pan. The heavy seed fall against the air flow until they are deflected by the inclined screen out the heavy seed discharge. With adequate air control, many precise separations can be made with pneumatic separators. Some of the physical characteristics that affect the buoyancy of an object and which are used to make pneumatic separations are specific gravity, surface texture, and shape.

I will demonstrate this laboratory seed blower. The sample is placed in the screen-bottomed section, and the plastic column is added that has two catch traps near the top. Then this screened cap with the adjustable air discharge is closed. The blower under the table is started which forces air up through the column. Notice that there is no movement of material with the air outlet closed. I will open it and watch how the light chaff begins to rise in the column and land in the catch traps. As I increase the opening allowing more air to escape, notice how another batch of material is lifted. This can be repeated and an infinite number of separations made until all the material is lifted, or you can stop at any point of separation. I will stop here so that the plump sound crimson clover seed will be left.

Figure 10 is a cross-section of a fractionating aspirator. Seeds are metered into the top of the air column at "A", the heavy seed fall against the air flow and out the air inlet "B". The lighter seed, shriveled seed, weed seed, grass seed, and chaff are lifted. By adjusting the incline of the air vane, the air column is changed so that the air velocity decreases and drops out material as it travels below its terminal velocity. Therefore, column "D" will receive the heavier liftings, which are usually good grain but not of the highest quality. Column "E" will catch salvage grass seed, broken kernels, and light and unusable grains. The light chaff, dust rodent filth and other extremely light material will be retained in column "F".

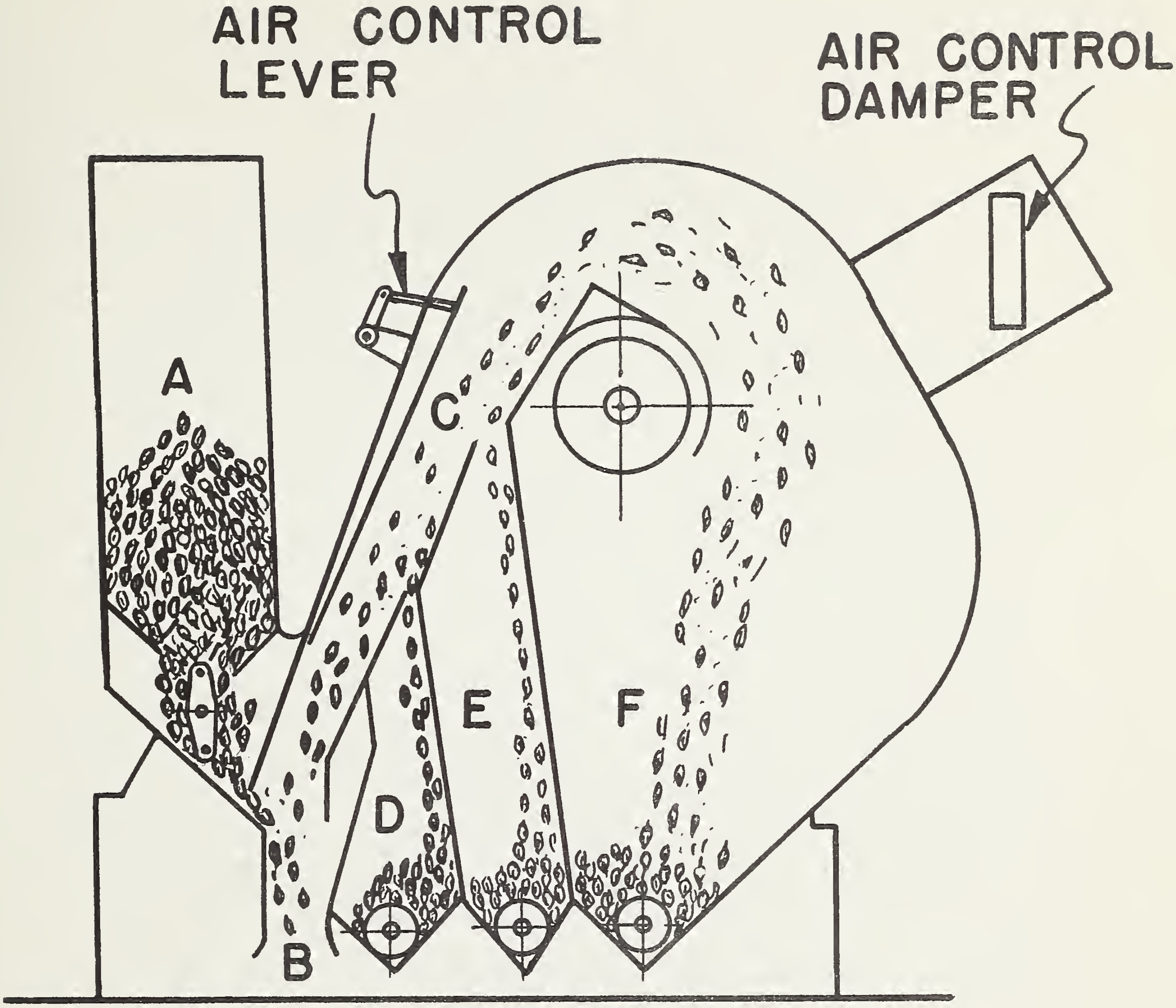
The air adjustment to obtain the desired air velocity at "B" is a baffle in the pipe here at "G" which is ahead of the suction fan and a variable speed drive on the electric motor. This unit accomplishes, in a continuous operation, what I demonstrated in several batch operations with the laboratory seed blower.

As seed processors become more familiar with pneumatic separators, use of this machine will be greatly increased as it is simple in operation, has good capacity, and makes accurate separations.



PNEUMATIC SEPARATOR

FIG. 9



FRACTIONATING ASPIRATOR

FIG. 10

THE VELVET ROLL SEED SEPARATOR

by
Jesse E. Harmond*

The velvet roll separator is a special seed cleaning machine that divides material by difference in shape and surface texture. It consists primarily of two velvet-covered rollers placed side by side in contact with one another, and set at an angle with the horizontal. The rolls rotate in opposite directions--outwardly when viewed from the top--and have an adjustable shield above them.

The seed mixture is fed onto the rolls at the upper end so that the seed travel down the incline formed by the rolls in contact. The rough-coated weed seed, sharp-pointed seed, and broken seed catch in the velvet and are thrown against the shield that reflects them back to the roll. They bounce back and forth in this manner until they are thrown over the roll and out of the mixture. The smooth-coated seed spin down the incline and are discharged from the lower end of the rollers. The separation is a graduated one with rougher seed being thrown out first, then a gradual reduction in roughness takes place as the seed approach the discharge or lower end of the rollers.

The velvet roll machine is similar to other seed cleaning machines in that it will not function properly unless adjusted to suit the crop and weather conditions. It will not make the intended separations unless the speed of the rolls, angle of incline, clearance between the shield and the rolls, and rate of feed to the rollers are all adjusted to the particular seed mixture requirements. The clearance between the rollers and the shield should be great enough so that the seed can turn freely without touching both shield and roller at the same time, but small enough that rough-surface seed will be repeatedly thrown against the shield as the seed comes in contact with the roller. When properly adjusted, the slick-coated seed such as clover will slide down the incline, rolling and spinning between the rollers. On the other hand, when rough-surface seed such as dodder come in contact with the velvet rolls, the seed are lifted so that they ricochet between the rollers and shield until they are thrown out. If the clearance is too great, many of the rough seed will spin and slide back between the rollers into the seed stream. If the clearance is too little, smooth seed will be pressed against the roller and rolled out with the rough-surface seed.

The rate of feed is rather critical on a roll machine. If it is too great, many seed will not come in contact with the rollers and will not be separated. The rate of feed and angle of incline of the rollers can be increased as the surface texture differential of the seed is increased, and vice versa. The speed of the rolls is another important factor and should be adjusted to suit the separation.

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* Head of Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A.R.S., U.S.D.A.

In adjusting the velvet roll unit, make only one change at a time. Run the machine five minutes, and then observe the results. If rough-coated seed are found in the smooth seed discharge, you are running the rolls too slow or are feeding the machine too fast. If there are too many smooth seed being thrown out with the rough seed, you are running the rolls too fast.

The velvet roll will make some unique separations, but has a low capacity and can be used only as a finishing machine.

THE SPIRAL SEPARATOR

by
Elmon E. Yoder*

The spiral separator is a finishing machine, used to separate seeds by relative ability to roll. Seed mixtures processed by the spiral are usually first given a preliminary cleaning by an air and screen separator.

The spiral separator consists of a vertical cylinder or body of galvanized sheet iron surrounded by one or more spirals of suitable form. Each spiral is constructed from rings of metal whose internal diameter is larger than the diameter of the body by an amount sufficient to give the desired pitch to the spirals. The basic separating mechanism of this type separator resembles an open screw conveyor standing vertically. There are no moving parts to the machine.

In operation, a mixture is fed to the inner spiral at the top of the machine. As the seed mixture travels down the inner flight, the round shaped seeds have a rolling motion. The other seeds tend to slide along the top surface of the helical flight and do not attain as great a velocity as do the round-shaped seeds. The momentum of the round-shaped seeds increases until they roll over the outer edge of the inner flight. The round seed continues rolling downward on the second flight and is subjected to further separation on any additional outer flights, while the flatter seed continues to slide downward along the inner flights.

Spiral separators are usually provided with multiple flights; each flight having its individual discharge ports. Seeds discharging from the inner flights are the flatter seeds, while the rounder-shaped seeds are discharged from the outer flights.

An example of a seed lot applicable to spiral separation is a mixture of vetch and cross-broken kernels of wheat. This is a mixture which may be impossible to separate further by screens or by length separation. The vetch and broken kernels of wheat may vary so little in least dimension or in length that separation based on size is impossible. Since the round vetch seed roll more easily than do the cross-broken wheat kernels, a separation may be made by the spiral on a basis of relative roundness of the seeds.

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* Agricultural Engineer, Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A.R.S., U.S.D.A.

An advantage of this type separating machine is its simplicity. It is entirely automatic in operation--other than maintaining a uniform feed rate. The separator requires little floor space, and is portable.

A disadvantage of the machine may be its limited capacity. Capacity can be increased by installation of additional units. Although this device is not as versatile as some of the other mechanical cleaners, it is simple and inexpensive; and is quite useful in performing a separation based on relative roundness of seed shapes.

THE ROTARY DISC SEED SEPARATOR

by
Elmon E. Yoder*

The rotary disc seed separator is designed to roll spheroidal seeds from other shaped seeds less inducive to rolling. Separating action of the rotary disc is obtained by imparting a centrifugal force to the seed.

This separator is a finishing machine. It performs best when the seed mixture has been given initial cleaning by an air and screen separator.

The rotary disc seed separator consists of a steel framework supporting a vertical rotating hollow shaft. Attached to this shaft at regularly spaced intervals are sixteen circular rotary tables.

In operation, the seed mixture is fed from a hopper into the top of the vertical hollow shaft. At each of the sixteen circular tables the seed is metered from the shaft through adjustable orfices, allowing the seed to flow uniformly over the inner area of the circular tables. As the tables rotate, the seed is confined to the inner area of each table by a plastic retaining fence. Two feed ports at each fence are adjusted to allow the desired rate of feed to be metered from the inner area. Seed passes through the ports to the outer areas of the rotating table. Speed of rotation is adjusted to force the spheroidal seeds to roll off the edge of the table into discharge hoppers. Other seeds remain on the tables for one-half revolution and are brushed off into discharge hoppers. The separator makes 32 individual separations, two for each table.

The outer area of the circular table has a slightly dished shape, that is, the top surface area is concave. The concave outer area allows a net outward horizontal force due to centrifugal force to remain constant regardless of position of seed on the table.

By operating the machine at various speeds, more or less centrifugal force is exerted on the seeds with subsequent variation in percentage of mixture reaching the various discharge hoppers.

Feed rate through the orfices of the vertical shaft, and feed rate through the two ports at each retaining fence depend upon the type of seed being run. The manufacturer lists capacities of 300 to 500 pounds per hour, with the higher capacities associated with seed mixtures of the greatest contrast in seed shape.

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* Agricultural Engineer, Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A. R. S., U. S. D. A.

PROCESSING DIFFICULT-TO-HANDLE SEED

by

Norman R. Brandenburg*

Certain types of seed, particularly native grasses, prove very difficult to handle throughout processing and planting operations. In some cases, this is due to seed appendanges such as awns, beards, or fuzz that tend to interlock and cause undesirable clustering. In other seeds, the presence of multiple florets or "doubles" prevents uniform handling and metering. Still another problem is posed by light, chaffy seeds which bridge easily and fail to flow properly from a gravity-feed hopper. Seed characteristics like these make a pre-conditioning treatment necessary to improve flow properties before such seed can be cleaned and planted with conventional machinery.

In the past, several mechanical actions have been investigated as a means of removing awns and appendages--these include the hammer mill, a thresher operating at high speed, a tumbling pebble mill, and a debearding machine. Since all these units employ a vigorous abrading action, care is needed in their operation to insure maximum awn removal with minimum seed damage.

Feed rate, hammer speed, screen selection, and crop condition all are very important in operation of the hammer mill. The screen should have an opening slightly larger than the de-awned seed. If too large a screen is chosen, there will be an excess quantity of inert matter and a high percentage of awns not removed from the seed. If the screen is too small, the seed will show excess damage and the capacity will be decreased. The feed should be regulated so that the mill is approximately full at all times. If the mill is operated only partly full, there will be more seed damage and a higher percentage of awns not removed.

The speed of the hammer mill best suited for pre-treating seed for cleaning is about 50% of that used in a normal grinding operation; however, this can vary slightly as to individual cases. If the speed of the hammers is too fast, the seed will be mutilated, cracked, or groated. If the speed is too low, awns will not be removed effectively. With a properly adjusted and operated hammer mill, most seed can be conditioned so that an air-screen machine can be used for cleaning. Seed of the following species has been successfully milled in a hammer mill operation: bluebunch wheatgrass (Agropyrom spicatum), blue wild-rye (Elymus glaucus), Canada wild-rye (E. canadensis), Siberian wild-rye (E. sibiricus), tall oatgrass (Arrhenatherum elatius), bulbous barley (Hordeum bulbosum), squirreltail (Sitanion hystrix), alfileria (Erodium cicutarium) and virgins-bower (Clematis liqusticifolia).

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* Agricultural Engineer, Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A.R.S., U.S.D.A.

Canada wild-rye has also been de-awned in a threshing operation by speeding up the cylinder, setting concaves to a minimum clearance, and reducing the air blast. However, moisture content at time of threshing is quite influential in thisprocess. Another pre-cleaning treatment that is effective in removing seed hairs and fuzz is the practice of tumbling a seed lot in a container with smooth pebbles. A sample of Marion bluegrass (Poa pratensis) tumbled in this type of unit and then treated with pneumatic and screen separators responded very well and showed improved flow properties.

Debearding machines are also used as pre-conditioners. There are at least two available types. One is approximately five feet in length with a circular cross section, and has a rotating member with rectangular beater arms set on it at a slight angle. Stationary bars mounted on the sides and protruding toward the center keep the seed mass from rotating with the beaters. The seed is fed at one end and conveyed through the unit by the pitch of the beater arms. Pressure or density of the seed in the debearder is regulated by a weight outlet door at the end opposite from the feed, and a variable speed pulley permits a selection of beater speeds. When these adjustments are set according to the peculiarities of the seed being processed, many of the range grasses can be cleaned. However, a high beater speed will cause seed damage, and some groating. Too much weight on the outlet door will reduce machine capacity, whereas too little weight will allow seed to escape early and reduce the percentage of seed de-awned.

The second type of debearder is somewhat similar in operation to the unit just discussed, but uses 1-1/2" pipe beater arms in place of rectangular bars. The shape of the feed box tends to reduce rolling of the seed mass, and de-awning is accomplished by the seed rubbing against each other. In limited preliminary tests, this type debearder appears to be doing a more efficient and less damaging job of removing awns and breaking up doubles than either the hammer mill or the debearder discussed previously. Also, it requires less horsepower to operate. However, awns that are not stiff enough to break and are small and limber like the awns of Black grama grass cannot be removed by this machine. Even after a lot is processed in debearders, hair-like awns often keep this seed from flowing over screens and further treatment may be required.

As a unique approach to the problem of awn removal, differential burning has some possibilities. This technique is somewhat similar to flaming grass out of cotton. In a laboratory experiment, the fine awns of Black grama seed were burned off by dropping the seed through a blow torch flame where an instant flashing of awns took place. No scorching of the paper-like lemma and palea was evident, and no increase in seed temperature could be detected by feeling the seed.

Conventional air-screen seed cleaners, with alteration, may satisfactorily handle some of these range grass seeds. To move seed over the screen, it may be necessary to mount the screens on arms so that the cam will give the screen a straw-walker action rather than a straight reciprocating motion all in one plane. To prevent choking or lodging of seed in screen openings, a knocker that periodically taps the screen may be required in addition to traveling brushes on the under side of the screen.

The aspirator cleaner can be used to good advantage both before and after air-screen cleaning operations. Here, the air adjustment is very accurate and close separations of a mixture may be made. This unit was used to process a sample of Meadow foxtail (Alopecurus pratensis) containing Watergrass, Quackgrass (Agropyrom repens), Ryegrass (lolium spp), and Rattail fescue (Festuca myuros). After one pass through the aspirator, the Meadow foxtail and Watergrass were lifted and the remainder of the contamination was discharged from the bottom chute. A No. 8 indent cylinder was then used to remove the Watergrass, leaving 99% clean Meadow foxtail.

Mechanical and electrical vibratory feeders offer some possibilities in conveying and handling troublesome seed mixtures. The oscillating action of these units together with suitable restraining arms tends to reduce agglomerations of seed, stem, and chaff material during transport. Relatively good feed control may then be obtained.

Many schemes have been used to obtain seed flow through planters. Mechanical agitators, brushes to clean the seeder disc, and free-flowing additives such as sawdust, sand, cracked grain, plastic shavings, and rice hulls have been used. Heavy materials like sand (which is abrasive and should not be used) and cracked grain have a tendency to settle below the light seed, resulting in uneven seeding. Sawdust and rice hulls are better additives, the latter being more desirable. The hulls are light and form a natural pocket to hold the seed. One rule-of-thumb for seeding is to set a planter for 160 pounds of barley per acre, and at this setting it will deliver about 16 pounds of rice hulls per acre. The desired amount of seed can then be mixed with the hulls, and the mixture will flow through the planter.

In conclusion, it should be pointed out that the methods and equipment described here represent only a preliminary approach in improving flow characteristics of certain seeds. The problem is challenging, but, like many others in agriculture and engineering, may be solved with continued research.

FLUIDIZED SEED CONVEYING

by
Norman R. Brandenburg*

An important requirement of efficient seed processing is the handling and transporting of seed lots so that damage and intermixing are minimized. Present seed laws in the United States are exacting as to germination and purity requirements, and future regulations are expected to be even more restrictive.

Seed testing laboratories frequently report mechanical damage in beans, vetches, crimson clover, tall oatgrass, wheat, and other crop seeds. Germination of beans, for example, has been found to decrease when the crop is dropped from heights of 12 inches or more. And even though a damaged seed may germinate, the plant often does not have the vigor of a plant grown from undamaged seed. Research workers have also shown that a damaged seed is more susceptible to fungus diseases and has a reduced storage life.

Generally speaking, seed handling methods can be divided into two major classifications -- mechanical and pneumatic. Mechanical methods include various types of elevators, conveyors, augers and bulk-handling schemes, while pneumatic systems refer to the use of air. Any one of these handling methods is capable of doing a good job in a certain application, but each also has its limitations.

Conventional cup elevators, to cite one case, have a high discharge velocity that may cause excessive damage to beans or other injury-sensitive seed. Also, small seeds have a tendency to lodge in hard-to-clean sections of the elevator and remain there to contaminate subsequent lots. Pneumatic conveyors, with their inherent self-cleaning characteristics, are better suited for pure seed handling, but seed may be easily damaged in transit when high air velocities are used for conveying. Air speeds as great as 6000 fpm are not uncommon in transporting heavy seeds, whereas studies have shown that seed damage increases rather sharply, depending on the crop, at conveying velocities above 3000 fpm.

A special type of air system that has recently drawn considerable interest in other processing industries is referred to as "fluidized" conveying. A mass of material is said to be fluidized when it acts like a fluid. If air is permitted to bleed up through a bed of particles,

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* Agricultural Engineer, Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A. R. S., U. S. D. A.

the bed will expand and become more loosely packed. With additional air, the individual particles tend to lose contact with each other, and the entire mass displays fluid-like properties -- sometimes even with a rippling surface.

Although chemical and petroleum industries have done much work on fluidization, their main concern has been to provide favorable conditions for a catalyst to accelerate chemical reactions and not necessarily to transport material. The idea of conveying in the fluidized state is relatively new but, reportedly, has been used successfully for such finely ground products as flour, cement, powdered coal, and ceramic materials.

Fluidized flow is considerably different than conventional pneumatic conveying. Velocities and power requirements are usually much less, solid-air ratios are considerably greater, and the conveying pipe smaller. The accompanying table* shows typical figures for the two systems.

	Conventional	Fluidized
Velocity (fpm)	3,000 to 9,000	600 to 1,200
Solid-air Ratio, by Wt.	0.5:1 to 4:1	75:1 to 200:1
Power Req. (hp/ton/hr)	2 to 7	0.8 to 2.5
Air Pressure (psi)	1/4 to 4	5 to 20
Conveying Line Size (in.)	3 to 30	3/4 to 4
Conveying Rate (lb/hr)	4,000 to 600,000	3,000 to 60,000

* Based primarily on the transport of small particle-size material such as flour or powdered clay.

Probably the most interesting features of fluidized systems are the low conveying velocity and the high solid-air ratio which, under some circumstances, can exceed 200:1, by weight. This low conveying velocity is especially important with respect to seed injury. Two other advantages of this type system are better dust control due to low air flow and relatively simple installation.

At this point, it should be emphasised that fluidization is being discussed generally in terms of fine-grained material such as powders. The picture may well change when a relatively coarse material such as legume or grass seed is considered.

To study the possible applications of fluidizing in seed processing, research is being conducted jointly by the U. S. Department of Agriculture and the Oregon Agricultural Experiment Station at Oregon State College, Corvallis, Oregon. Main objectives of the work underway are to determine

what seeds can be fluidized and to what extent, the velocities required to convey fluidized seed, the solid-air ratios that result, the power requirements and pressures associated with this type flow, what conveying rates may reasonably be expected, and how the pipe run affects operation. Seed damage will also be investigated, especially with respect to conveying velocity, pipe size and elbow curvature. To accomplish this program, an experimental unit was constructed in the seed research laboratory at Corvallis employing a positive displacement blower, a rotary airlock feeder, a means of introducing seed into the airstream, and a run of conveying pipe. At the present, the unit is still in the development stage.

To date, testing of the system has taken place in three stages. In the first, using a fluidizing chamber and a 12 foot run of one inch pipe, it was possible to obtain a steady dense flow in which seed nearly filled the conveying line. Seed velocities, by direct measurement, were less than 200 fpm and air pressures ranged up to 10 psi. Maximum conveying rates were about 1500 pounds per hour when transporting lotus (Birdsfoot trefoil). Rates could be increased, at the expense of greater velocity and lower solid-air ratio, to approximately 4000 pounds per hour through the one inch pipe. The dense phase flow was found stable at some rates and unstable at others.

The second stage of the work took place with a 55 foot run of one inch pipe, eight feet of it vertical. With this system, a different flow type was obtained. Rather than in a steady dense or lean flow, lotus seed moved throughout the run in surges. This pulsating pattern is apparently composed of fluidized "slugs" traveling throughout the system. Pressures ranged up to 10 psi and seed velocities, which were difficult to measure, were estimated at less than 1000 fpm. Although the flow was not continuous, maximum conveying capacities averaged about 1100 pounds per hour.

In a brief study of mechanical injury to beans, sample lots of an easily damaged variety (Topcrop) were conveyed through the 55 foot run with various moisture contents, discharge methods, flow types, and number of repeat runs. Germination and breakage counts showed several test conditions that satisfactorily transported the material with little or no damage. Maximum bean velocities were about 700 fpm through the one inch pipe.

The third stage of the research, now underway, eliminates the fluidizing chamber, uses $1\frac{1}{2}$ inch aluminum pipe for the conveying run, and employs the injection of auxiliary air at downstream points in the run. An adapter unit replaces the chamber and permits a direct transfer of seed from airlock to conveying pipe. Flow in this system again takes place in a surge or slug pattern. In a 17 foot run (10 feet of it vertical) crimson clover was transported at rates from 1000 to 3000 pounds per hour. Blower line pressures varied from 4 to $5\frac{1}{2}$ psi, and

total power requirement for the system was about 2 HP including airlock consumption and transmission loss through two variable speed drives. Under best operating conditions, this resulted in a power requirement of about $1\frac{1}{2}$ HP/ton/hr. A flow of colored seed through the system was timed, and seed velocities averaged 80 fpm at a conveying rate of 1140 pounds per hour. The highest solid-air ratio obtained was about 25:1.

When additional $1\frac{1}{2}$ inch pipe was added to provide a 58 foot run (10 feet of it vertical) the flow characteristics were relatively unchanged, but maxium conveying rates dropped to 1400 pounds per hour. As would be expected, pressure requirements were increased and greater amounts of injection air were used. Total power requirements increased to about $2\frac{1}{2}$ HP, and seed velocities, again by direct measurement, were found to be 85 fpm. Generally speaking, operation with the longer run appeared more stable than with the short run. In all setups examined, thorough cleanout between lots was easily accomplished by increasing air velocity through the system.

Crops that have been transported in the experimental fluidized conveyor are red clover, lotus, crimson clover, hairy vetch, and beans. Future plans are to experiment more extensively with the unit by varying horizontal and vertical components of the run, and using longer sweep elbows and smoother pipe. Supplemental air will also be injected at more downstream points to help overcome the friction caused by the addition of elbows and pipe. Automatic control of system pressure will be studied as a means of regulating seed flow, and two blowers in series will be used if a higher pressure supply is needed.

Although fluidized seed conveying is now only in the development stage, it appears to have considerable promise. Mixtures and damages in the farmers' seed conveying system can be minimized and clean-up labor should be sharply reduced.

THE BUCKHORN MACHINE

by
Leonard M. Klein*

Principle of Operation

The principle of separation is that foreign material can be made to adhere to certain seed thus changing its size and specific gravity. The surface of buckhorn seed is mucilaginous and when moistened with water, will pick up foreign material with which it comes in contact.

Description

The buckhorn machine is designed specifically for the separation of buckhorn from alfalfa and clovers. The seed mixture, along with water and finely ground hardwood sawdust, is introduced into a continuous auger-type mixing chamber. With moisture, the buckhorn becomes sticky and is enlarged by picking up sawdust. The enlarged buckhorn may be removed from the mixture by an air screen cleaner. If some of the buckhorn is still too near the same size to be screened out, the gravity separator may be used to make a separation.

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* Agricultural Engineer, Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A.R.S., U.S.D.A.

THE INCLINED DRAPER SEPARATOR
by
Leonard M. Klein*

Principle of Operation

The inclined draper separates seed on the basis of a difference in their ability to roll or slide down an inclined surface. The rolling or sliding characteristics of seeds are governed by their shape and seed coat texture.

Description

The inclined draper separator is a rather special type of cleaner not commonly found in commercial cleaning plants. It is regarded as a finishing machine and does the specialized job of removing a single crop or weed seed from the mixture. The seed mixture is metered from a hopper onto a draper traveling in an uphill direction. See Figure 11. Round seed will roll and smooth seed will slide down the draper faster than the draper is travling up the incline, while flat or rough seed will adhere to the draper and be carried to the top of the incline. The seed dropping off the draper at its lower end is gathered in one chute and that reaching the upper end is dropped into a second chute. To gain capacity in commercial operation, several ten foot wide drapers are used in a single machine.

Adjustments

The rate of feed to the draper may be varied. The rate should be slow enough to allow each seed to act individually and not be hindered from rolling or sliding by those that are stationary or be forced to move by those that are traveling. The angle of incline may be varied to match the rolling or sliding characteristics of the seed mixture. The speed of the draper may be varied to simulate a shorter or longer length of incline. Belts with different degrees of roughness may be used as the draper. A relatively rough canvas belt may be selected when rolling is involved with the lower fraction, while a relatively smooth plastic belt may be selected when sliding is involved with the fraction that drops from the lower end of the draper.

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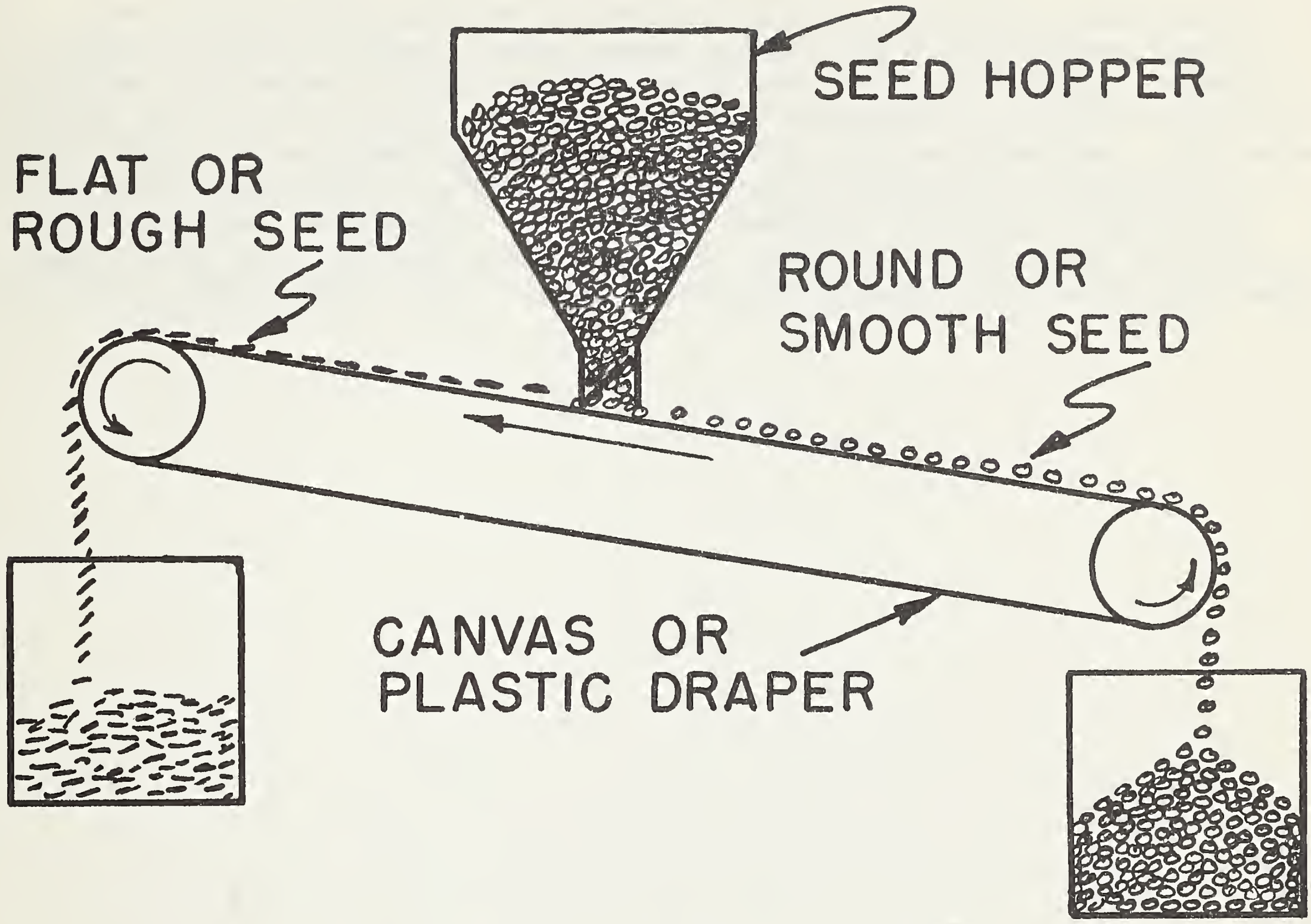
* Agricultural Engineer, Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A.R.S., U.S.D.A.



INCLINED DRAPER SEPARATOR

FIG. 11

Operation

In adjusting the machine to perform a given separation, start with a very low rate of feed, a slow draper speed, and a flat draper slope. Increase the angle of slope until none of the rolling or sliding fraction of the mixture is being carried to the top. Increase the draper speed until none of the adhering fraction is falling off the lower end. Increase the rate of feed until it becomes obvious that quantity is interfering with individual seed action and changing the previously set conditions, then reduce the feed rate a small amount. Separations that can be made by the inclined draper are crimson clover from grasses and vetch from oats.

ELECTROSTATIC SEED SEPARATION

by

Dean E. Booster*

Electrostatic separation of crop seeds depends upon the fact that different seeds possess different electrical properties. Electrical conductivity is one of the properties most often used in the electrostatic separation process. All materials conduct electricity to some extent, but some materials have a great deal more conducting ability than others. The greater the difference in the electrical conductivities of the crop seed and weed seed, the easier the two seeds may be separated. The electrostatic separation process, as used in seed cleaning, is essentially independent of the size, shape, weight or surface texture differences of the seeds.

Electrostatic separation is accomplished by the practical application of a phenomenon known to man as early as 600 B.C. It was about this time that the effects of rubbing a piece of amber with fur was observed. The amber, after being rubbed with fur, was "electrified" or charged with static electricity. In this charged condition, the amber was capable of "attracting" or lifting such lightweight objects as scraps of paper, strands of hair, and particles of dust. The modern counterpart of this ancient experiment is the rubbing of a hard rubber comb on woolen cloth. The rubbing action produces a charge of static electricity on the comb which enables the comb to attract pieces of paper and the like. Essentially, this is the basis of electrostatic separation. Some of the seeds are attracted to a charged electrode while other seeds are repelled from it. The attraction or repulsion of the seeds is governed by the electric charges on the seeds.

Electrically charged seeds, like other charged bodies, will obey Coulomb's law of electrostatics which states that a force exists between two charged bodies. This law may be written in the following form:

$$f = \frac{Q_1 \; Q_2}{K \; r^2}$$

where Q_1 and Q_2 = the respective electric charges of the two bodies.

r = the distance between the charged bodies.

K = a constant of proportionality which takes into account the medium in which the charged bodies are located and the system of units being used.

f = the force existing between the two bodies.

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* Agricultural Engineer, Agricultural Engineering Department, Oregon State College.

If the electric charges Q_1 and Q_2 are similar, that is both positive or both negative, the force f will be a force of repulsion and the charged bodies will tend to repel each other. On the other hand, if the charges are unlike, the charged bodies will be attracted toward each other.

In the electrostatic separator, the seeds are given a surface charge of electricity by being exposed to a high voltage electrode. Since the electrode is a current-carrying conductor, it is surrounded by an electric field. An expression of the force acting on a charged seed passing through this electric field may be obtained by rewriting Coulomb's law in the following form:

$$\frac{f}{Q_1} = \frac{Q_2}{K\ r^2}$$

where $\frac{f}{Q_1}$ = the force acting on a unit charged seed.

Electrostatic separation is dependent upon this force to deflect the seed from its normal path of travel through space. Differences in the amounts of deflection experienced by different seeds passing through the electric field will depend upon the magnitudes of the electric charge on the various seeds.

The electrostatic separator consists basically of a feed hopper, a feed belt, an electrode, and some adjustable dividers. The seeds receive their charge of electricity from the electrode. Assuming that all of the seeds have the same opportunity to acquire a charge, then the only way the charge on one seed can differ from the charge on another seed is if one seed loses part of its electric charge. The rate of removal or dissipation of the charge is a function of the conducting properties of the seed and the surrounding medium. The higher the conductivity of the seeds, the faster the rate of discharge. Seeds that are poor conductors retain a surface charge longer than good conductors. These poor conductors are repelled by the electrode and pinned to the feed belt because they have a surface charge of the same polarity as the electrode. Neglecting gravity, these seeds will remain in contact with the feed belt until the charge can leak off into the air or until the charge can redistribute itself over the surface of the seed and be discharged through the feed belt. Seeds that are relatively good conductors will not hold a surface charge long enough to be pinned to the feed belt. Consequently, these seeds will follow a flight path similar to that which they would follow if there were no charging effect at all.

The ideal seed mixture for electrostatic separation would be one in which one kind of seed was a good conductor of electricity while the other kind of seed was an extremely poor conductor of electricity. This, of course, is usually not the case in problem seed mixtures. Then too, seeds are subject to the peculiarities of nature and all of the seeds of a particular variety are not exactly the same. Consequently, seeds of a particular kind may have a fairly wide range of electrical conductivity. This makes a one hundred percent pure separation very difficult to obtain in many instances.

A factor which plays an important part in the electrostatic separation process is the moisture content of the seeds. The ability of seed to conduct electricity is affected by changes in moisture content. An increase in seed moisture content results in an increase in the rate at which the seeds will dissipate electric charges. Likewise, a decrease in seed moisture content causes the seeds to lose their surface charges much more slowly. If the changes in seed moisture content are great enough, the possibility of making a separation may be completely removed. It has been found that changes of from 2 to 3% in the seed moisture content are enough to impair some separations. Changes in moisture content may be compensated for within a limited range by changing the settings of the electrostatic separator.

The electrostatic separator is primarily a finishing machine. It will not replace the conventional seed cleaning equipment, but will supplement it. The electrostatic separator does not depend upon size, shape, weight, surface texture, or similar seed characteristics for making separations. But, instead, separations are made on the basis of differences in the electrical properties of the seeds. Therefore, the electrostatic separator offers a possible means of making separations that are extremely difficult or impossible with conventional seed cleaning equipment.

MAGNETIC SEED SEPARATOR

by
Jesse E. Harmond*

There are no less than one-half dozen magnetic separators used in the seed industry -- one German, one English, and three United States types. They are becoming increasingly popular as seed standards become more exacting. Magnetic separators are finishing machines with capacities ranging from 200 lbs. to 2000 lbs. of seed per hour, depending on the size of machine and the seed being cleaned. They are excellent for removing rough-coated weed seed from smooth-coated legume or flax seed, for removing cracked or parts of seeds, dirt clods, and seed like plantains that have a mucilaginous substance on the surface.

Figure 12 is a section view of a single drum magnetic separator. Most magnetic seed cleaners have two drums in series so that seeds are automatically cleaned with a single pass through the separator.

The seed mixture is fed into a screw conveyor that tumbles and mixes the seed with a proportioned water spray and a finely ground magnetic powder. The powder sticks to rough seed coats, cracks in a seed coat, dirt clods, chaff, or seed with a sticky residue on its surface. The mixture is discharged from the mixing screw onto the revolving high-intensity magnetic drum. The rough-coated or mucilaginous-coated seeds pick up powder during the mixing process and will therefore adhere to the magnetic drum until they are removed with the rotary brush. The good seed, free of magnetic powder, will not be attracted by the magnetic field and will fall in the normal manner, thereby facilitating the separation.

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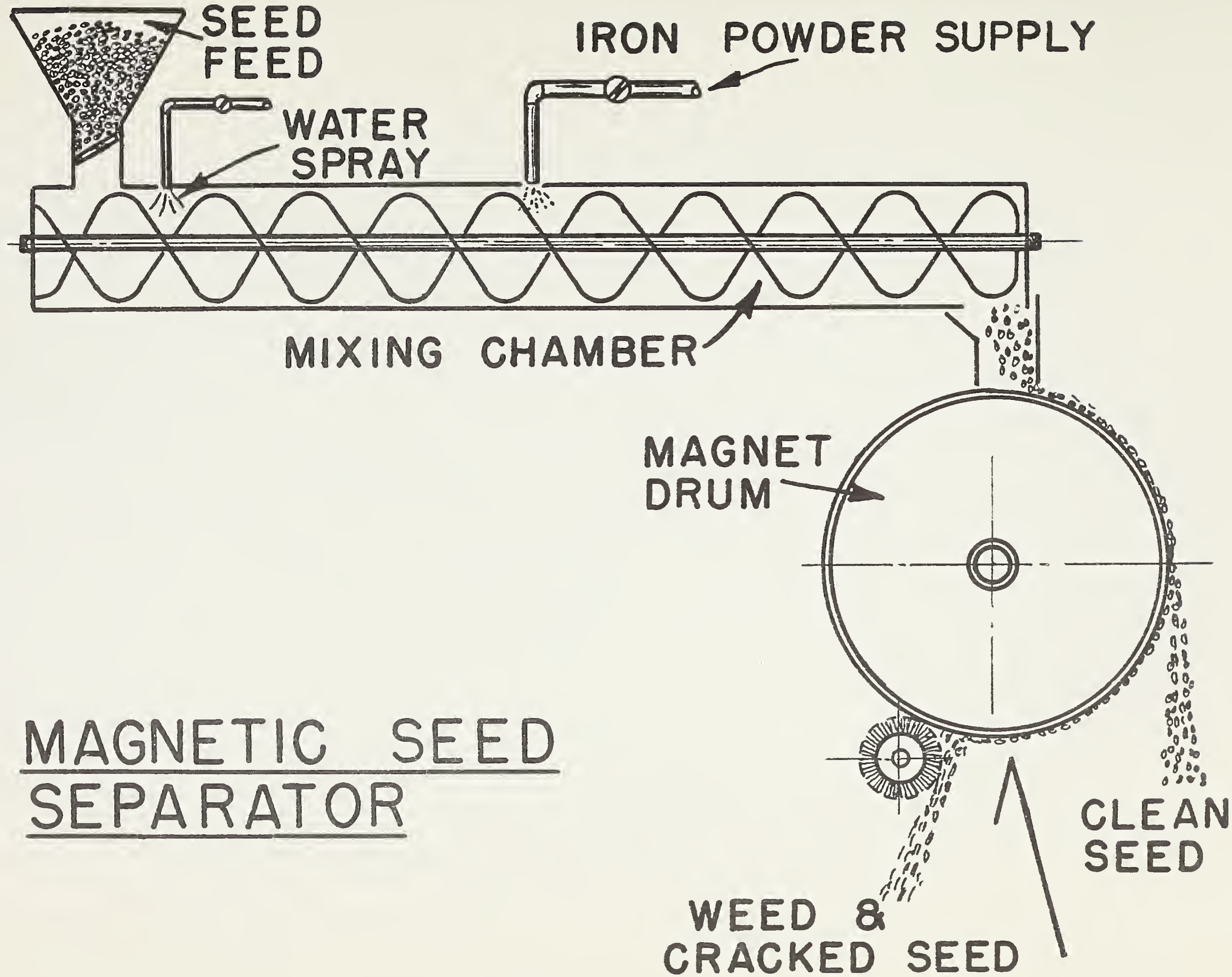
* Head of Small Seed Harvesting and Processing Section, Agricultural Engineering Research Division, A. R. S., U. S. D. A.



MAGNETIC SEED
SEPARATOR

FIG. 12